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The last 10 years can be considered the embryonic period for seafloor observatories, with the introduction of sizeable observatories off the west coast of Canada, the west coast of the United States, the Mediterranean Ocean and smaller observatories scattered throughout the world's oceans. The footprint for cabled observatories today is likely to pale in comparison to what is on the horizon. The increase in the number of long-term deployed subsea networks will bring development of processes and procedures for recovery, refurbishment and redeployment likely to set the standard for networks to come.

As we have now reached the 10th- and fifth-year anniversary of the OceanWorks International-designed and built Venus Cabled Observatory and CSnet's OCB (Offshore Communication Backbone), respectively, the long-term deployment of seafloor observatories is no longer a promise but a fact. OceanWorks International and CSnet are now cooperating in the recovery, refurbishment, upgrade and redeployment of CSnet's OCB Node Pods.

(Photo Credit: OceanWorks International)

(Top) Pod arrival at OceanWorks' Vancouver facility. (Bottom) OceanWorks electrical technician at work on electrical systems.

History

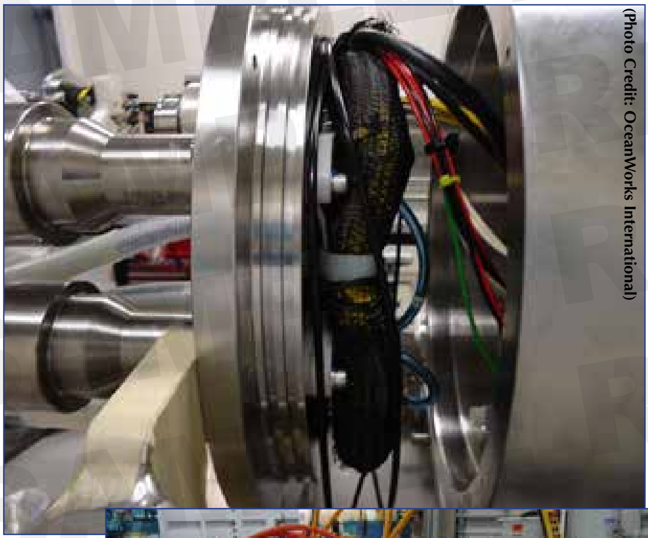
The OCB is a modular seafloor communications and power distribution network deployed at depths from 1,500 to 2,300 m. The extremely capable, customizable and upgradable system can provide telemetry, control and power distribution infrastructure that allows customers to accomplish a wide range of environmental monitoring, infrastructure monitoring and distributed control solutions.

The OCB, deployed in the Mediterranean Sea in 2010 and 2011 in two phases, was initially meant to serve as a testbed for a tsunami warning and early response system but has become of interest to the area's institutions, universities, government ministries and the offshore oil and gas industry. The system allows for expansion depending on future customer requirements. OceanWorks International and CSnet have worked together since the initial deployment to upgrade the system, with the design and delivery of two high-power nodes by OceanWorks in 2012 as a proof of concept and the delivery of the Poseidon Diode Interface (PDI) in 2013 to protect the OCB from unforeseen electrical faults in the cable. This work and the upgrade and refurbishment of the initial five pods started in 2014, testifying to the durability, upgradability and expandability of the OceanWorks-designed seafloor observatory.

Planning

Inherent to the Node Pod design is the ability to disconnect and recover the pod from the node base after being deployed on the seafloor. The pod has most of the critical power and communications components and can be removed from the node base in case of failure of a component, or to conduct scheduled maintenance. This design avoids the expense and need for a cable-lay vessel to recover the node to the surface.

After continuous operation for four years, a plan was de-



(Photo Credit: OceanWorks International)

(Photo Credit: OceanWorks International)

(Photo Credit: OceanWorks International)

(Top to Bottom) Pressure vessel undergoing disassembly. Refurbished and upgraded pod. Refurbished and upgraded pod delivered to CSnet.

veloped to recover and refurbish the five pods at each of the nodes of the OCB over several years. The first phase of the plan was the delivery of two spare pods from OceanWorks in December 2013 to be installed as temporary replacements for two deployed pods to be recovered for refurbishment and later put back in service (a process that has since been completed).

The next phase of planning was to develop the procedures for recovery and the requirements for a vessel of opportunity (VOO) to execute the pod exchange. This procedure includes vessel preparation, personnel requirements and rigging procedures for both the recovery and deployment of a pod. The vessel is required to have a dynamic positioning (DP) system with an ROV and a suitable A-frame heavy-lift system.

In addition to the vessel crew, the critical personnel required to conduct the recovery and deployment of a pod include DP operators on the bridge, back-deck riggers for the heavy-lift operations, and ROV operators experienced in mating/demating wet-mate fiber-optic/power connectors.

Recovery

Once a suitable VOO has been identified and chartered, mobilization preparations will start from a port close to the operational area. The pod software is configured specifically for the designated node and is shipped by sea freight to the port. In addition, the required rigging and support equipment is identified and mobilized to the vessel.

When the vessel is on site, a call will be made to CSnet's Network Operations Center (NOC) to secure all power on the OCB for an unpowered demating of the wet-mate connectors. Upon confirmation by the NOC that the system is unpowered and secured, the ROV will start demating the power and fiber-optic connectors between the node base and the pod. Then the sensor connectors will be demated and the pod cathode recovered back to the pod. Finally, the ROV will verify that a series of four mechanical latches are unlocked. In parallel, the heavy-lift line is lowered through the A-frame sheave toward the seafloor. Knowledge of the prevailing currents, precise navigation and critical vessel positioning are required to ensure that the ROV umbilical and heavy-lift line do not become entangled.

When the heavy-lift line is on the seafloor, the ROV will grab it with its manipulator and maneuver it to the node location for attachment to the central lifting pad eye of the pod. The ROV operators will ensure that all node/pod interconnectors and sensor cables are clear prior to lifting the pod. Then at a safe distance away from the node/pod, but still within visual range, the ROV operators will coordinate the lift with the heavy-lift winch operator.

The ROV will remain on the seafloor and inspect the node base while the pod is hoisted to the surface and brought on board. The back-deck rigging crew will secure the pod on deck and change out the rigging to deploy the replacement pod.

Deployment of Refurbished Pod

Prior to the start of the recovery and deployment operations, the replacement pod will be powered and tested for full functionality on deck. The pod will then be rigged to the heavy-lift line for deployment over the side. ROV and vessel positions will be verified with current taken into consideration before overboarding the pod. The pod will be lowered through the water to about 50 m off the seafloor in order not to disturb the soft silt bottom. Acoustic beacons are used to track and position the pod close to the node base with the assistance of the vessel's DP system. The ROV will use its sonar system to locate the pod and heavy-lift line before moving within visual range of the suspended pod.

Once the ROV has a camera view of the suspended pod, the pod will be lowered to about 10 m from the seafloor in preparation for final install into the node base. Coordination between the ROV and the vessel's DP operators will position the pod over the node base, and with some guidance from the ROV's manipulator the pod will be inserted into the node base.

The ROV operators will essentially reverse the recovery steps for the deployment of the replacement pod by starting with the release of the heavy-lift line, followed by mating of the node to pod power and communication interconnectors. A new cathode will be deployed approximately 12 m from the node pod, and the sensors will be reconnected.

When the ROV has verified that all wet-mate connectors have been mated into the proper connections, the

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vessel will contact the NOC to repower the OCB. The ROV will stand by the node/pod until the NOC has confirmed the functionality of the pod and the sensors in case the ROV has to intervene. When the NOC has verified full functionality, the ROV will surface. The recovered pod will then be shipped to OceanWorks' Vancouver facility, where the refurbishment process will take place.

Refurbishment Process

A five-year maintenance cycle was initially defined to allow for regular maintenance and refurbishment of a pod to ensure the pod's full functionality throughout its design life.

Upon receipt of the CSnet pod at OceanWorks International, an initial condition survey will provide a visual inspection of the pod and a high-level system test to uncover any potential issues prior to disassembly of the pod.

A detailed inspection will then be performed on critical components to ensure any and all opportunities for improved durability are identified and functionality is ensured for the next deployment cycle. The entire refurbishment process can be quite lengthy due to replacement of custom components and long lead times, so OceanWorks International and CSnet have acquired all of the custom components in advance, reducing the refurbishment time by almost half. Completion of the third pod refurbishment is planned for June 2016.

Testing and Verification

After the initial condition survey, there will be a detailed inspection with functional testing to baseline the pod performance prior to performing refurbishment. This detailed inspection will be completed during disassembly of the equipment to provide a general mechanical assessment of the structure and sealing surfaces and a detailed test to verify the functionality of internal electrical systems. All pressure vessels are opened during this phase and inspected for a variety of issues, including corrosion and water ingress. Based on the results of the electronic functional testing and mechanical inspection, a refurbishment plan will be created. Reassembly and retesting of the pod are next. Functional testing is performed at every level of the assembly process to ensure all assemblies and subassemblies meet operational requirements. A final factory acceptance test (FAT) is performed upon completion of the pod assembly process to ensure full system functionality prior to shipment.

Structural Refurbishment

To ensure the longevity of the structural elements of the pod, a structural refurbishment is required to make repairs and restore the cathodic protection system during regular maintenance activity. This refurbishment includes, at minimum: removal of any corroded metal; replacement of structural elements as required; and refurbishment of the cathodic protection system, including repainting of the pod frame and installation of new sacrificial anodes. The structural refurbishment must be completed prior to reassembly of the pod and is done in parallel to any repairs or upgrades to the electronic and connector systems.

Electronics Refurbishment

The electronics refurbishment comprises two parts: the refurbishment or replacement of any components that experienced issues during deployment and the initial condition survey or detailed inspection, and updates agreed upon by OceanWorks International/CSnet required to enhance system functionality and reliability.

Upgrades are performed based on customer feedback and experience gained from previous pod refurbishments and from other projects using pod technology. When it is determined that system upgrades are necessary, an analysis is performed to determine the extent of the work and risk required to modify the component, compared to the cost of replacement. Due to the long-term reliability requirements for subsea systems, and the high cost of recovery if an unforeseen event occurs, it is generally more cost effective to replace a component rather than upgrade it.

Connector Refurbishment

Part of the refurbishment process is to ensure that the system is updated to allow for the latest technology to increase the reliability and longevity of the system. Thus, dry mate connectors are updated to allow for greater compatibility with the cathodic protection system. Wet-mateable connectors are also refurbished as required. This work can include remedying any lazy actuators in optical or hybrid connectors and adding hardware to improve system reliability.

Conclusion

The refurbishment process is considered complete upon successful FAT at OceanWorks International, attended by witnesses from CSnet. The third pod is now undergoing the refurbishment process and will benefit from insights from the two previous pods. Indeed, we are in the enviable position of being the first to establish not only the procedures and processes required for the refurbishment/upgrade of seafloor observatory Node Pods and associated systems after long-term deployment, but also being able to provide lessons learned from two successfully completed refurbishments. **ST**

Leonard T. Whitlock is general manager for CSnet International, Inc., responsible for interfacing with clients from the scientific, academic, governmental and marine industry sectors. His focus is on ocean observing systems and collection of oceanographic and metocean data. He has over 40 years of diverse, worldwide experience in the marine and oceanographic industry working with research submersibles, offshore oil and gas structures, marine archeology, search and recovery, and submarine rescue systems.

Scott Williams is the systems engineer for seafloor networks at OceanWorks International. In the last three years, he has worked closely on several seafloor networks now deployed in the west coast of Canada, the Mediterranean Sea and the China Sea. He has over six years of experience completing high-reliability designs in the transportation, industrial power and subsea industries, with the last three years focusing on the power distribution and control systems required for seafloor networks.

Chad Gunderson is a project manager for OceanWorks International who joined OceanWorks in 2004, initially as an electronics technician. His grasp on continual technological innovation has ensured his progression through the company. Gunderson has extensive global experience in field repair, system integration and providing customers with operations-critical equipment training.